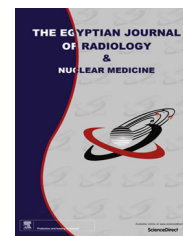




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ORIGINAL ARTICLE

# The role of multi-detector computed tomography with 3D images in evaluation and grading of renal trauma



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## KEYWORDS

MDCT;  
Blunt and penetrating renal  
trauma;  
Grading;  
3D

**Abstract** *Objective:* The aim of this study was to assess the role of multi-detector computed tomography with 3D images in evaluation and grading of renal trauma.

*Patients and methods:* The study comprised 50 patients clinically suspected of having renal trauma examined with MDCT.

*Results:* This retrospective study included 50 patients clinically suspected of having renal injury referred to MDCT. Males are more exposed to trauma than females. Blunt trauma represented in 40 cases (80%) and penetrating trauma in 10 cases (20%). According to AAST renal trauma was graded as follows: In blunt trauma (40 patients), 11 cases were grade I renal trauma, 8 cases were grade II, 8 cases were grade III, 7 cases were grade IV and 6 cases were grade V. In penetrating trauma (10 patients), 3 cases were grade III, 4 cases were grade IV and 3 cases were grade V. Isolated renal injury was noted in 14 cases (28%) and renal injury associated with multisystem trauma noted in 36 cases (72%).

*Conclusion:* MDCT is the modality of choice in evaluation and grading of renal trauma with high sensitivity (90–100%). CT detects site and extension of renal trauma and assesses the excretory function. CT is advantageous for the selection of best patient treatment.

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**Abbreviations:** MDCT, multidetector CT; CECT, contrast enhanced CT; PCS, pelvicalyceal system; FAST, focused ultrasonography; MVA, motor vehicle accident.

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## 1. Introduction

Urinary tract injuries occur in 3–10% of all abdominal trauma patients, the kidney being the most commonly injured organ. The vast majority (80–90%) of cases are secondary to blunt abdominal trauma. The most significant renal trauma is associated with injury to other major organs (1–10).

Multidetector computed tomography is considered the gold standard method for the radiographic assessment of patients with renal trauma and has completely replaced IVP (11–15). With a short examination time, CT provides all the necessary information relating to the degree of parenchymal injury with or without involvement of PCS and renal vascular injuries and also provides information regarding the functional status of the kidneys. Doing a phasic scan also helps in differentiating active hemorrhage from urine extravasation. With the wider availability of newer CT machines and helical multislice scanners, much faster scanning, increased volume coverage and improved multiplanar reconstruction ability now can provide high quality images with shorter time on the table for the patient. As most of the patients undergoing CT scan are not so co-operative in breath holding, motion artifacts can frequently compromise the study and lead to added confusion in interpreting the scan. Faster imaging with multislice scanner and multiplanar reconstruction can help to overcome these problems and provide an accurate assessment of injury (16–18).

CT information frequently increases the diagnostic confidence of the surgeons and influences clinical management decision and plays an important role in decreasing the rates of unnecessary exploratory laparotomy (18).

Renal injuries are classified into grades 1–5 based on the severity of the injury using the American Association for the Surgery of Trauma (AAST) organ injury severity scale (19):

- Grade 1: Contusion or nonexpanding subcapsular hematoma without parenchymal laceration.
- Grade 2: Nonexpanding perirenal hematoma laceration < 1 cm deep without extravasation.
- Grade 3: Laceration > 1 cm without urinary extravasation.
- Grade 4: Laceration extending through renal cortex into collecting system, or segmental renal artery or vein injury with contained hemorrhage, or partial vessel laceration, or vessel thrombosis.
- Grade 5: Laceration: shattered kidney, or renal pedicle injury, or avulsion of renal hilum.

Hematuria is a characteristic sign of renal trauma. However, there is no correlation between the degree of hematuria and the severity of the renal injury. This surgical-pathologic classification system recognizes the progressive nature of parenchymal and vascular damage associated with increasingly severe mechanisms of trauma (20).

## 2. Aim of the work

The aim of this study was to evaluate the role of multi-detector CT with 3D images in the evaluation and grading of renal trauma.

## 3. Patients and methods

This study was approved by the ethics committee of our institution. All patients clinically suspected of having renal trauma were advised to undergo MDCT scan.

The study comprised 50 patients (40 males and 10 females) that were clinically suspected of having renal trauma from May 2013 to May 2014.

*Inclusion Criteria:* Patients clinically suspected of having renal trauma and all were hemodynamically stable (see Tables 1 and 2).

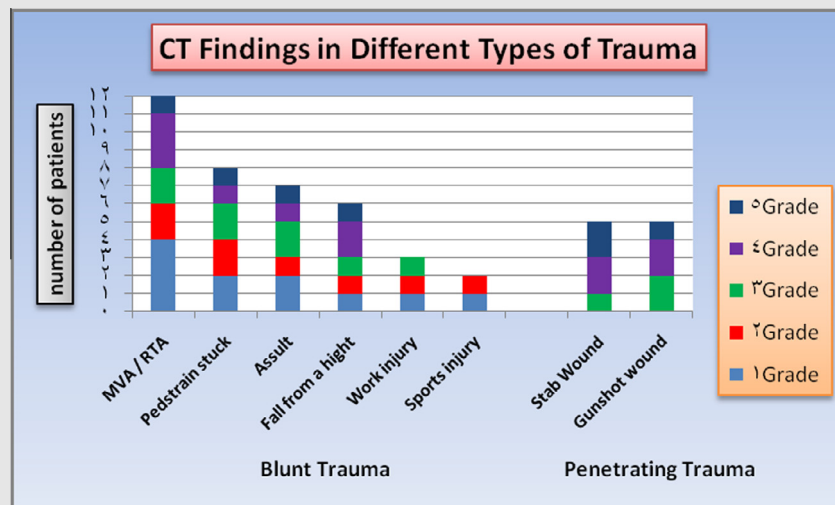
*Exclusion Criteria:* Our exclusion criteria were severely shocked patients who couldn't be transported to CT unit, patients with serum creatinine levels greater than 1.5 mg/dl, or those with known allergies to iodinated contrast agents.

All patients are subjected to following:

- 3.1. Complete history taking: including patient age, sex, occupation, time and type of trauma, side and mechanism of injury, past urological history or chronic renal diseases.
- 3.2. Through clinical examination including vital signs: blood pressure (BP), pulse rate (PR) and respiratory rate (RR).
- 3.3. General assessment: according to the role of A B C D E F G H: airway, breathing, circulation, disability, exposure, funds examination, hypothermia
- 3.4. *Radiological assessment:* All patients in this prospective study undergo the following:
  1. Focused Assessment with Sonography for Trauma (FAST) using 3.5 MHz probe (GE Logic 5, GE healthcare, USA). The use of focused ultrasonography (FAST) has now become an extension of the physical examination of the trauma patient and is conveniently used in the primary survey and triage of patients (11–15). Mostly, kidneys are imaged as a part of the routine abdominal scan performed to look for injuries of other commonly injured abdominal viscera. It can detect renal lacerations but

**Table 1** Mode of renal injury.

Mode of injury		Total No.	Total %	Male	Female
Blunt trauma (40 cases)	M V A/RTA	14	28	10	4
	Pedestrian struck	8	16	4	4
	Assault	7	14	7	0
	Fall from a height	6	12	4	2
	Work injury	3	6	3	0
	Sports injury	2	4	2	0
Penetrating trauma (10 cases)	Stab wound	5	10	5	0
	Gunshot wound	5	10	5	0
Total		50	100	40	10

**Table 2** MDCT findings in different types of renal trauma.

Mode of trauma	Total		Grade 1		Grade 2		Grade 3		Grade 4		Grade 5	
	No	%	No	%	No	%	No	%	No	%	No	%
Blunt trauma	40	80	12	24	9	18	6	12	7	14	6	12
MVA	14	28	5	10	2	4	1	2	3	6	3	6
Pedestrian	8	16	2	4	2	4	2	4	1	2	1	2
Assault	7	14	2	4	2	4	1	2	1	2	1	2
Fall from height	6	12	1	2	1	2	1	2	2	4	1	2
Work injury	3	6	1	2	1	2	1	2	0	0	0	0
Sports injury	2	4	1	2	1	2	0	0	0	0	0	0
Penetrating trauma	10	20	0	0	0	0	3	6	4	8	3	6
Stab	5	10	0	0	0	0	1	2	2	4	2	4
Gunshot	5	10	0	0	0	0	2	4	2	4	1	2
Total	50	100	12	24	9	18	9	18	11	22	9	18

cannot definitely assess their depth and extent and does not help in differentiating extravasated blood from urinoma. Small lesion could missed, with a retroperitoneal hemorrhage or when there is a concomitant other solid visceral injury present. In the presence of hematuria, even a negative scan does not rule out an underlying injury and a decision on further management is based on the clinical status of the patient (2,3). The protocol for the management of patients with suspected renal injury broadly divides patients into three groups: (1) patients with hemodynamic instability usually warrants surgical exploration, whereas patients who have been stabilized after initial poor scores may undergo a CT scan or a repeat FAST and further decisions can be taken accordingly; (2) patients who are hemodynamically stable and have hematuria should undergo a CT scan; and (3) patients who are hemodynamically stable, have no hematuria and negative FAST results should be followed up with clinical observation of at least 6 h duration (11–15).

## 2. Multidetector Computed Tomography (MDCT):

All MDCT examinations were performed using 16 detectors CT scanner (GE bright speed, GE healthcare, USA) with the following parameters:  $4 \times 5.0$ -mm detector configurations, 3.0 pitch, 15.0-cm/s table speed, and 7.5-mm section thickness. Image reconstruction at 5-mm intervals can be performed retrospectively when vascular injury is suspected. Multiplanar reformatted and three-dimensional images generated from axial source images can provide a great deal of additional information.

### 3.1. Patient preparation

Every patient was given 500–750 mL of water over a 15- to 20-min period before the start of a renal CT examination. Each patient was instructed to remain stable and do not move during examination. Axial cuts were taken from the dome of the diaphragm to the symphysis pubis. Monitoring devices, tubes and wires were positioned out of the scan plane.

### 3.2. Administration of intravenous contrast medium

Patients were given 100–120 mL of non-ionic contrast medium (scan lox) at an infusion rate of 4 mL per second. Contrast was

injected through an 18-gauge angiocatheter placed in the antecubital vein followed by 250 mL of saline infusion to provide better visualization of the collecting system.

### 3.3. Imaging protocol

- (1) An initial nonenhanced study was obtained to detect acute bleeding or intraparenchymal hematoma that may become isoattenuating relative to the normal renal parenchyma at post-contrast CT.
- (2) A portal venous phase 45–60s after initiation of contrast injection (75–100 mL) of nonionic contrast agent, 300–400 mg concentration of iodine was administered to all patients using automatic injector at rate of 2–3 mL/s; therefore, the kidneys will be imaged during the late cortical or early nephrographic phase, which allows identification of parenchymal lacerations and devascularized segments, if any. Also, optimal contrast in the renal arteries at this time helps to evaluate renal pedicle injury.
- (3) Both arterial (25–30s) and nephrographic (60–80s) phases were obtained when renal pedicle injury is highly suspected.
- (4) 5 min delayed scan was obtained to detect pelvicalyceal system injury and urinary extravasation. Also it confirms an arterial extravasation if seen in the earlier scan, which will now be seen to spread with contrast density higher than that in the adjacent arteries.

### 3.4. Image reconstruction

The axial thin cuts were sent to the workstation (Syngo CT 2006A-W, SIEMENS, Germany), for axial, sagittal and coronal planes. Volume rendering techniques (3D) and CT angiography were displayed for further clarification.

### 3.5. Image analysis

All images from MDCT studies were reviewed by two radiologists for detection of Contusions and hematomas: Renal contusions characterized by a focal area of decreased enhancement in the renal parenchyma relative to normal adjacent regions.

Subcapsular hematomas may vary in attenuation value as a function of the age of the clot. Acute hematomas are typically hyperattenuating (40–60 HU). Lacerations: renal lacerations appear as linear, and low-attenuation areas in the parenchyma may be superficial (<1 cm depth) or deep (>1 cm depth). Urinary extravasation: Active hemorrhage tends to track into surrounding tissues and has a linear or flame like appearance, whereas false aneurysms tend to be more focal and rounded. Renal Infarction typically appears as peripherally based, wedge-shaped areas of parenchyma that fail to enhance during both the corticomedullary and pyelographic phases of CT study. Shattered kidney refers to gross renal parenchymal disruption by multiple lacerations. Devascularization of the entire kidney due to laceration or to in situ thrombosis of the main renal artery constitutes the most severe form of renal injury (grade 5).

## 4. Results

### 4.1. Demographic data

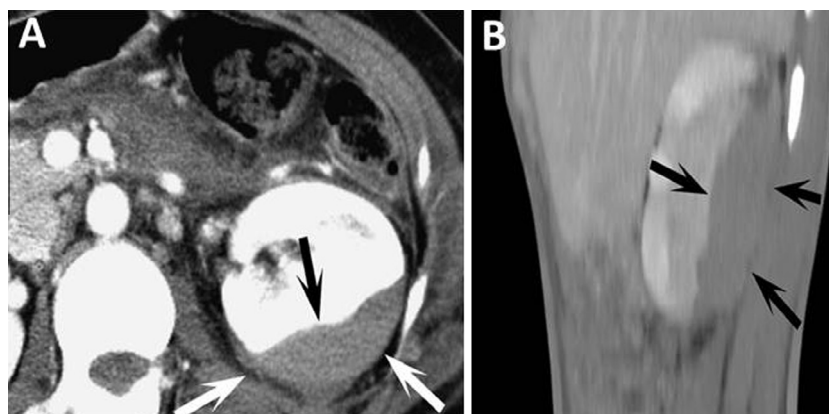
This study included 50 patients clinically suspected of having renal injury referred to MDCT unit. The age ranged from 6 to 65 years with mean age 40 years in males and 30 years in females. Males are more exposed to trauma than females and the ratios were 80% males to 20% females.

### 4.2. Types and cause of renal trauma

Blunt trauma was represented in 40 cases (80%) and penetrating trauma in 10 cases (20%), motor vehicle accident (MVA) being the most common mode of blunt renal trauma followed in order of frequency by pedestrian struck, assault, fall from height, work and sports injury with stab and gunshot wounds were of same frequency. Flank pain, abdominal tenderness and gross hematuria were the most common presenting symptoms.

### 4.3. MDCT findings

Grading of renal trauma was evaluated according to the AAST organ injury severity scale:



**Fig. 1** Female patient, 26-year-old with grade I left renal injury. (A) Contrast-enhanced axial CT scan at early excretory phase shows crescent-shaped fluid collection (arrows) between renal capsule and renal parenchyma. (B) Sagittal reformats shows fluid collection (arrows).

- (A) In blunt trauma cases (40 patients), 11 cases were grade I renal trauma (Fig. 1), 8 cases were grade II trauma (Fig. 2), 8 cases were grade III (Fig. 3), 7 cases were grade IV (Fig. 4) and 6 cases were grade V (Fig. 5).
- (B) In penetrating trauma cases (10 patients), 3 cases were grade III, 4 cases were grade IV and 3 cases were grade V (Fig. 10).

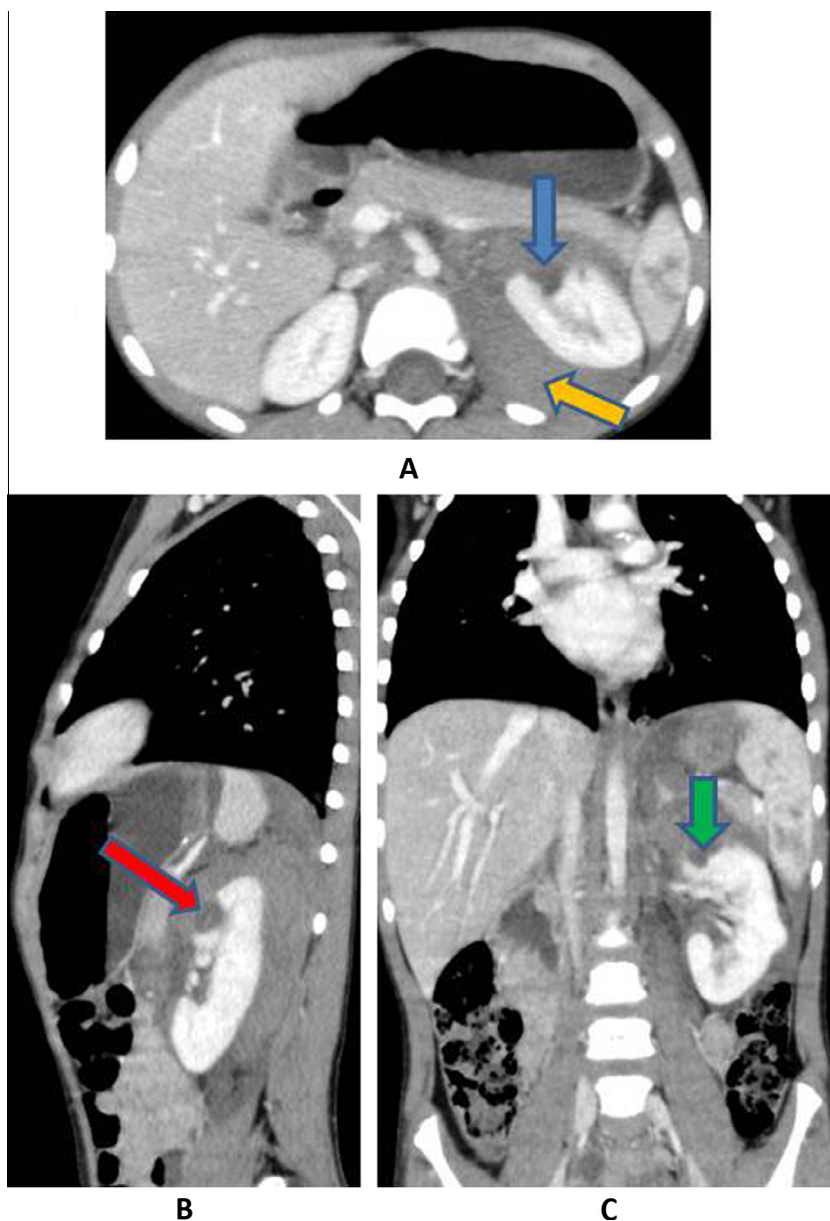
Isolated renal injury was noted in 14 cases (28%) and renal injury associated with multisystem trauma was noted in 36 cases (72%) (Fig. 6).

Liver was the most common organ associated with renal injury followed by the spleen (46%, 30% respectively).

Preexisting renal lesions were detected in the form of 3 cases with renal cyst, 2 cases with renal stones, 1 case with horse shoe kidney (Fig. 7) and 1 case with pelvi-ureteric junction obstruction.

All cases detected by CT and treated surgically were matched to MDCT findings (true positive 18 cases), also the remaining 32 cases that were treated conservatively were also matched to CT findings, and this means no false negative or false positive cases with 100% sensitivity and specificity.

Complications were seen in the form of 2 cases of secondary hemorrhage, 2 cases of urinoma collection (Fig. 8), 2 cases of hydronephrosis and 1 case of renal vein thrombosis associated with polytrauma to brain chest and abdomen (Fig. 9), renal abscess, hypertension, and renal scarring.

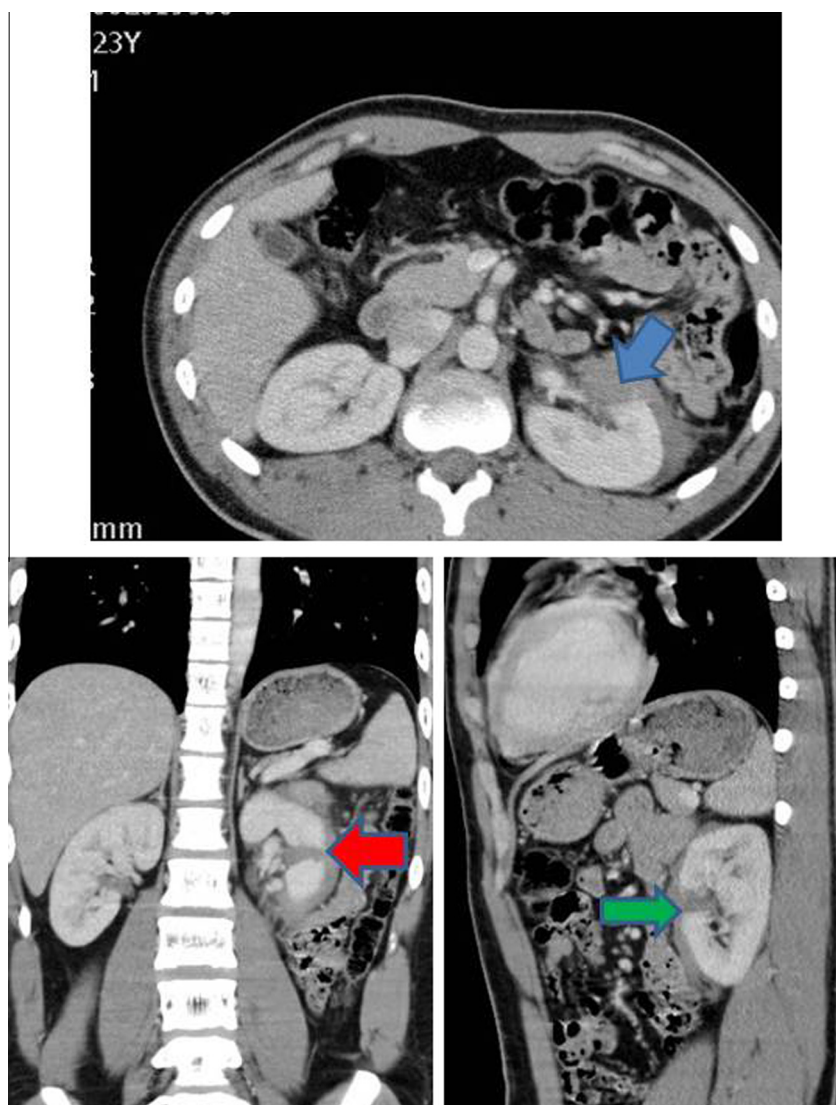


**Fig. 2** 8-year-old children with grade II injury to left kidney. (A) Contrast-enhanced CT scan at corticomedullary phase shows cortical laceration (blue arrow) and perinephric hematoma (yellow arrowhead). (B) Sagittal and (C) coronal reformats show cortical laceration yellow and green arrows respectively.





**Fig. 3** 5-year-old boy with grade III left renal injury. (A) Contrast-enhanced CT scan at early excretory phase shows cortical laceration (arrow) more than 1 cm deep and perinephric hematoma. (B) Thin-slab maximum intensity projection in oblique coronal plane shows laceration (arrow) and hematoma.



**Fig. 4** Male patient 23-year-old boy with grade IV injury to left kidney. (A) Axial CT corticomedullary phase shows laceration through parenchyma and collecting system (blue arrow). (B) Thin-slab maximum-intensity-projection CT scan in coronal plane obtained at corticomedullary phase shows laceration throughout parenchyma (red arrow). (C) Sagittal reformat revealed renal laceration (green arrow).

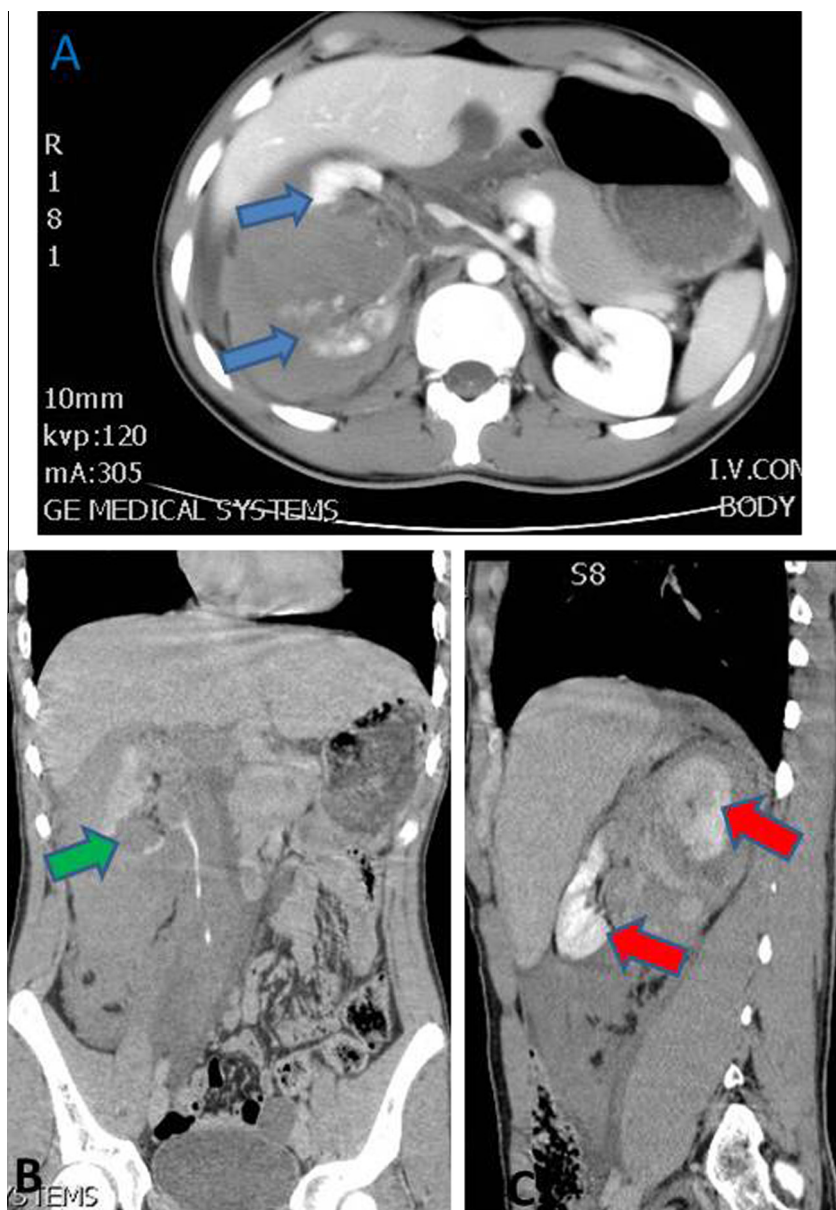
## 5. Discussion

No single method of evaluation can be uniformly applied to all patients suspected of suffering abdominal trauma. The exact approach depends not only on the types of injuries the patient has likely suffered but also on the philosophy of the attending physicians, local practice, and the type of equipment and support available (21).

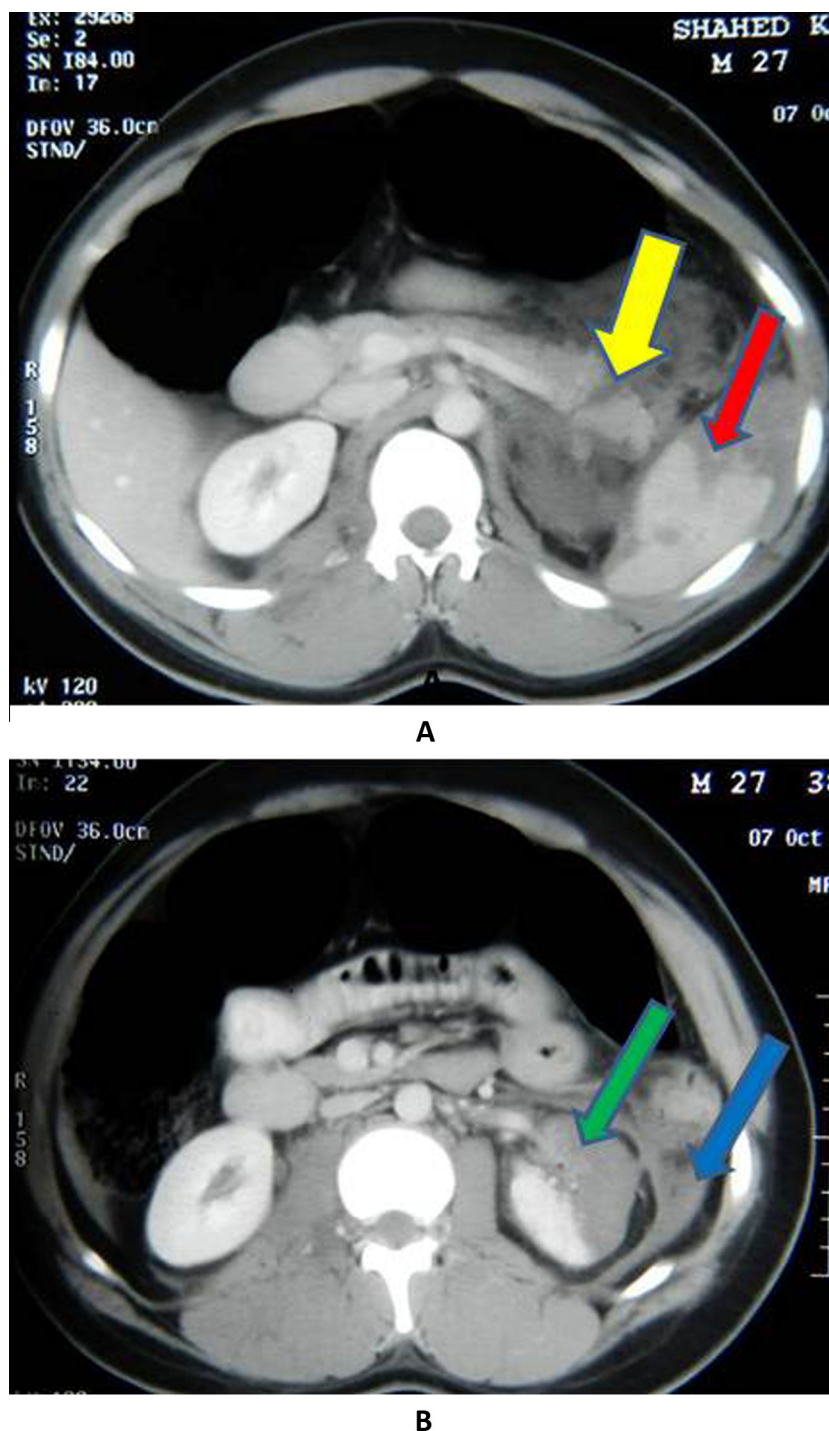
Renal injury from different types of trauma posed a challenge to clinicians in giving accurate diagnosis. Many of these patients were the victims of multiple injuries and the clinical signs and symptoms of the intraabdominal injury may be masked by more obvious or compelling injuries elsewhere. However, MDCT can provide a rapid and accurate appraisal

of the status of the abdominal viscera, retroperitoneum and abdominal wall. The use of MDCT has influenced the current trends in the management of blunt intraabdominal injuries toward nonoperative managements (22).

The age distribution in this study follows the same age distribution in worldwide studies with some differences, like no females patients included in the age between 11 and 30 years and this may be due to this age group are less exposed to social aggressive activities and daily works. Males are more exposed to trauma than females with significant difference from 80% to 20% and this is accepted and well known in all studies on trauma due to more exposure of men to trauma than women. Also male patients are more exposed to blunt abdominal trauma than females 30/50 to 10/50. Most of the male patients



**Fig. 5** Male patient 20 year old with grade-V right renal trauma (Shattered kidney). Contrast enhanced axial CT showed shattering of the right kidney by avulsion of the ureteropelvic junction and laceration of the renal vessels with extravastion of contrast. (A) Axial (blue arrows), (B) coronal reformats (green arrow) and (C) sagittal reformats (red arrows).



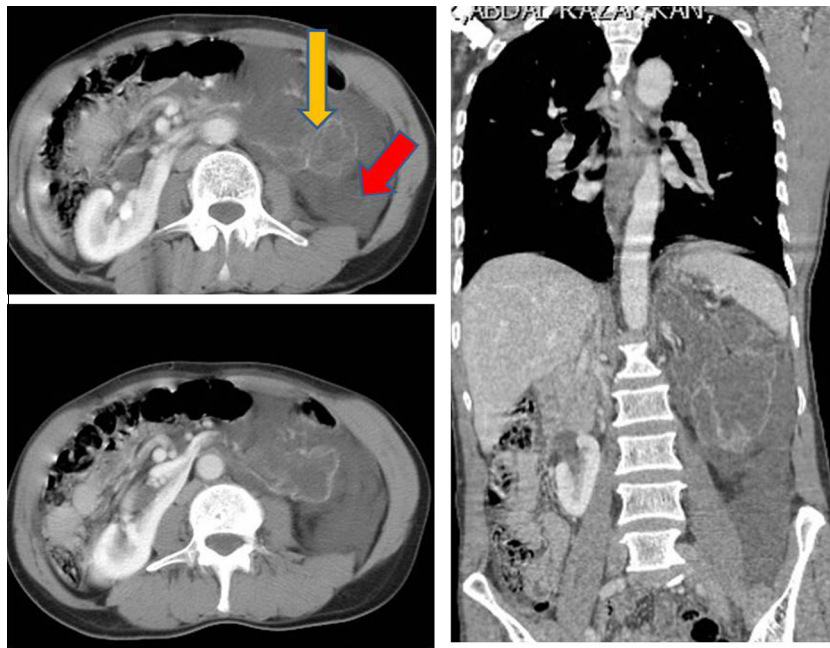
**Fig. 6** Male Patient 27 year old with multi-organ trauma. (A) Axial contrast enhanced CT corticomedullary phase showed pancreatic (yellow arrow) and splenic laceration (red arrow). (B) Axial enhanced CT cortico-medullary phase showed subcapsular hematoma (green arrow) and perinephric collection (blue arrow).

involved in motor vehicle accidents were in the range 21–40 year age group.

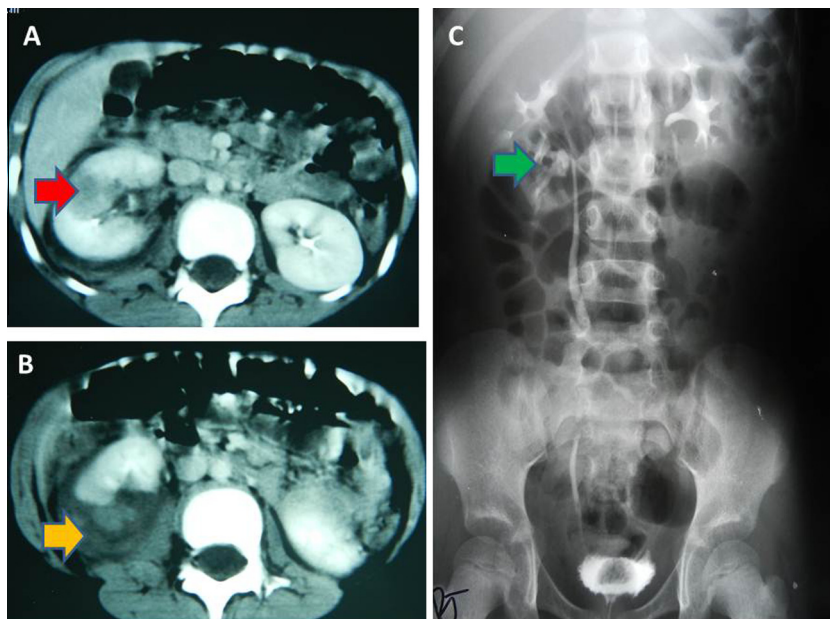
Gross hematuria was found in all patients, which matches with the other studies but with different percentages which were attributed to serious renal and other organ injuries. This matches with Alonso et al. (23) who stated that no significant urinary tract injury occurs in the absence of gross hematuria.

Blunt abdominal trauma is responsible for most closed injuries of the genitourinary organs and accounts for up to 80–90% of all cases, with motor vehicle crashes being the most common cause while penetrating trauma accounts for approximately 10% of all renal injuries; however, its incidence is increasing (23). In our study, 40 patients (80%) suffered from closed blunt trauma.





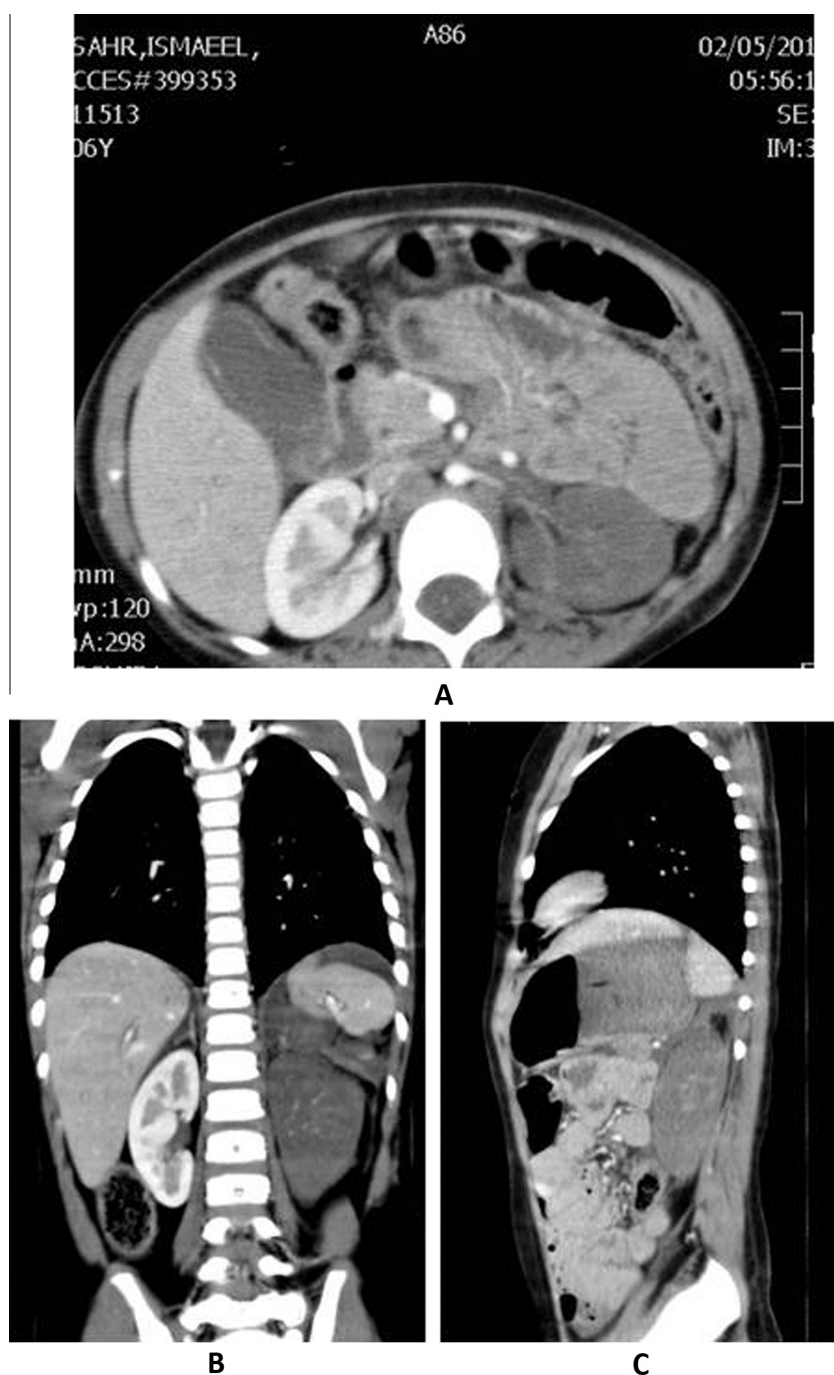
**Fig. 7** Ruptured horseshoe kidney. Axial contrast CT at the early excretory phase, coronal and sagittal reformats showed ruptured left horseshoe kidney (orange arrow) with peri-nephric collection (red arrow).



**Fig. 8** Complicated right renal trauma by urinoma formation. Axial CT showed right renal contusion and laceration (red arrow) and urinoma formation (yellow arrow) and IVP showed indentation of urinoma upon the lower calyceal system and contrast leak (green arrow).

FAST examination was done for all patients and variable amounts of intraperitoneal and retroperitoneal collection were detected; however, its sensitivity in detection of retroperitoneal collection was 90.5% (perinephric collection was missed in 5 out of 50 patients). This matches with Alonso et al. (23) and Smith et al. (24) who stated that ultrasonography has low sensitivity (44–95%) for the detection of retroperitoneal blood and retroperitoneal injury.

Contrast Enhanced Computerized Tomography (CECT) examination was performed for all patients and the CT findings were classified according to the ASST grading system. Regarding these criteria Grade I injury was diagnosed in 12 patients (24%) having small contusion without laceration nor perinephric hematoma, and this matched with Alonso et al. (23) and Smith et al. (24) who mentioned that Grade I injuries are the most common type of renal injury (75–85%



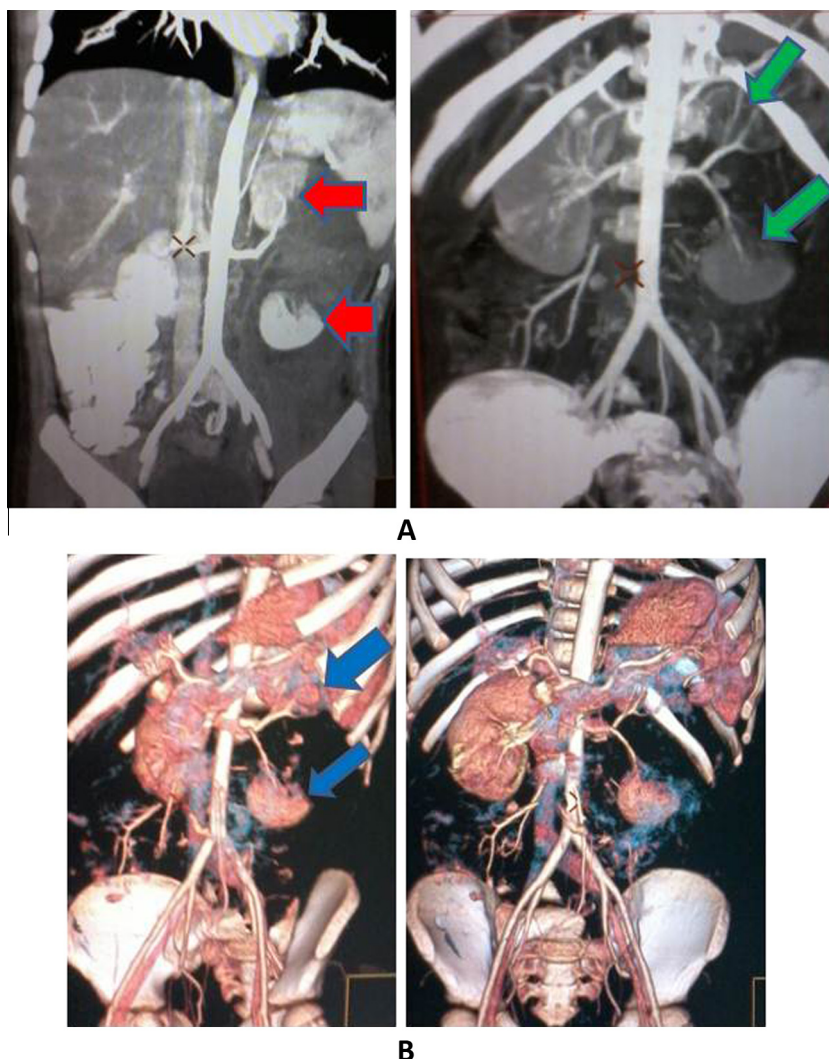
**Fig. 9** Left renal vein thrombosis associated with poly-trauma to the brain, chest and abdomen. (A) Axial CT corticomedullary phase, (B) coronal and (C) sagittal reformats revealed absent enhancement of the left kidney. Left subphrenic collection also noted.

of cases). In a large series reported by Miller and Mc Aninch (25), 82% of injuries were classified as grade 1 (parenchymal contusion, isolated subcapsular hematoma), minor parenchymal lacerations (grade 2) accounted for 6%, major lacerations (grades 3 and 4) for 7%, and vascular injuries (grades 4 and 5) for only 5% of cases.

Serious renal injuries are frequently associated with injuries to other organs. Multiorgan involvement occurred in 75% of patients with blunt abdominal trauma and 60% of patients with penetrating abdominal trauma. Kwashima et al. (26) mentioned that multiorgan involvement occurs in 75% of

those with blunt trauma; however, it differs regarding its association with penetrating trauma that he mentioned that it occurs in 80% of patients with penetrating trauma. This may be due to the fact that most patients with penetrating trauma included in this study had stab injury directed toward the flanks resulting in isolated renal injury.

Alonso et al. (23) and Kawashima et al. (26) mentioned that preexisting renal abnormalities predispose the kidneys to an increased risk of injury and a decreased potential for renal salvage following blunt abdominal trauma, this is confirmed in this study which includes 7 patients (14%) with



**Fig. 10** 3D images for grade-V left renal injury (A) surfaces shading and (B) MIP showing shattered left kidney (red, blue and green arrows) in a child 10 year old with history of penetrating injury.

preexisting renal anomalies who suffered renal injury following blunt abdominal trauma, three patients who had bilateral renal cysts which ruptured in one patient and became hemorrhagic in the other one, renal stones in two patients who suffered expanding subcapsular hematoma and congenital anomalies namely horse shoe kidney in one patient who had deep laceration at its isthmus with pelvicalyceal system injury and pelviureteric junction obstruction in another one who suffered pelvic tear.

The most commonly injured intraabdominal organ associated with renal injury was the liver (46%) followed by the spleen (30%), and this is consistent with Ramchandani et al. (21) who stated that the liver and the spleen are the most common intraabdominal organs to be injured with blunt trauma.

Twenty-three patients in the current study presented renal lesions associated with intraparenchymal hepatic hematoma or hepatic dilacerations, and majority of them, 20 cases (40%) were grades II and III injuries, were managed conservatively. Three cases (6%) of grade IV liver injury were found, and treated surgically. Jeffrey et al. (27) state that CT staging of blunt hepatic injuries has little discriminatory value in

predicting outcome of stable patients, as nearly all have an excellent prognosis.

The second most commonly injured organ was spleen accounting for 30% (15 out of 50) of injuries, with grade III being the most common grade. All these cases were managed conservatively. Three cases of grade V injury were detected, and they were associated with grade V renal injury, all of which underwent surgery for splenectomy in addition to renal repair. Becker et al. (28) in their study found that, CT findings in splenic trauma cannot be used to determine reliably which patients require surgery and which patients can be treated conservatively. Even patients with splenic parenchymal injuries of CT grades III, IV and V can be successfully treated conservatively if the clinical situation is appropriate, whereas delayed splenic rupture can still develop in patients with low CT grades. The choice between operative and non-operative management of splenic trauma should be mainly based on clinical findings rather than CT findings.

Two cases of grade IV pancreatic injuries detected in this study were stable, and managed conservatively. Hence we cannot effectively judge the accuracy of CT in pancreatic injuries



based on our study. Ilahi et al. (29), in their study found that CT was 68% (19 of 28) accurate in diagnosing pancreatic injury. They concluded that CT scan is only moderately sensitive and can underestimate or miss pancreatic injury. Although CT moderately correlated with injury grade it was highly predictive for the presence of injury.

Seven cases of bowel injuries were found during abdominal exploration, six of them were diagnosed based on CT findings and one case was missed and diagnosed on CT as isolated hemoperitoneum of grade I. The sensitivity in this study for diagnosing bowel injuries was approximately 85%. All CT findings of hemoperitoneum and/or solid organ injury were confirmed in these cases, and an additional one case of bowel injury was diagnosed. CT was 100% sensitive in detecting renal injury and hemoperitoneum.

Sclafani et al. (30) consider CT the method of choice for renal injuries and confirmatory angiography unnecessary. Lupetin et al. (31), using CT, diagnosed renal artery occlusion in all seven patients with renal trauma in their series. He mentioned that CT and angiography were equal in their usefulness for predicting the location of the injured portion of the renal arterial system in the four patients in whom preoperative angiography was performed. Although CT did not specifically show the point of obstruction in the renal artery or its branches that were shown angiographically, the location of the occlusion could be inferred by determining whether the distribution of the unenhanced parenchyma was total or segmental. CT showed retroperitoneal hematoma that was not visible on angiography in two cases. Angiography did not reveal any abnormalities that were not shown with CT. Lang et al. (32), on the other hand, found CT less reliable in the detection of trauma to the renal artery, as the diagnosis was missed on CT in five of seven patients in their series.

The overall sensitivity and specificity in this study with respect to CT renal injury findings guiding patient management were 100% and 100% respectively. The positive predictive value was 100%, and accuracy of this study was 98%. The reduced overall sensitivity as regards other organ injury was entirely due to the reduced sensitivity of CT in detecting bowel injuries. CT was highly accurate with respect to other visceral injuries in this study. Kumar, Venkataramanappa et al. (33) determined an overall sensitivity, specificity and positive predictive value (for trauma detection by CT) of 93%, 100% and 100% respectively.

## 6. Summary and conclusion

CT become the imaging modality of choice for the evaluation of renal trauma and other associated injuries, providing the essential anatomic and functional information necessary to determine the type and extent of parenchymal, vascular, or collecting system injuries with high sensitivity (90–100%). Improvements in CT technology are advantageous for the patient selection for the best treatment and thus to prevent failure of non-operative management.

## Conflict of interest

No conflict of interest statement.

## Agreement form

All authors agreed for publishing this research paper.

## Disclosure statement

No disclosure of funding was received for this work from any organization.

## Authors' contribution

All authors have appraised the article and actively contributed in the work.

Nasr Mohamed M. Osman participated in data collection, techniques, image interpretation, revision and final editing.

Mohamed Gaber Eissawy participated in sharing in data collection and image interpretation.

Adel Moustafa Mohamed participated in patient selection, clinical data and patient management.

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